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PEAK CANCELLATION CREST FACTOR REDUCTION TECHNIQUE FOR OFDM SIGNALS

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ABSTRACT

High peak-to-average power ratio (PAPR) problem encountered in the transmission of modern communication signals such as orthogonal frequency division multiplexing (OFDM) is solved by Crest factor reduction (CFR) techniques. They reduce the magnitude of the less frequent peaks occurring in the signal and achieve lower PAPR, Peak Cancellation Crest Factor reduction (PC-CFR) is a relevant CFR technique that is capable of large PAPR reductions while EVM and spectral mask constraints are met. In this paper, we generate the PC-CFR algorithm and simulate this algorithm to show that it is a practical technique that can be readily implemented. More than 5dB of PAPR reduction can be achieved with this algorithm.

KEYWORDS: PAPR, OFDM, CFR

INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) has been a popular scheme for communication systems because of advantages over single-carrier schemes such as abilities to resist to frequency-selective fading, to use guard interval to remove inter-symbol interference, etc. However a major disadvantage is that OFDM communication systems must deal with high peak-to-average power ratio (PAPR), which degrades efficiency of power amplifiers and hence causes complexity of designing, and also requires a high dynamic range from digital-to analog/analog-to-digital converters [1].

In third generation (3G) and fourth generation (4G) the modulated signal has no longer constant envelop signals, compared to conventional GSM signal in second generation (2G). Therefore either the linearity of the power amplifier (PA) should be increased or the signal amplitude above some certain threshold should be clipped off. High linearity requirements lead to low power efficiency and therefore to high power consumption. So to achieve the good PA efficiency the peak-to-average ratio (PAR) must be reduced, i.e. the signal must be clipped. In transmitter side hard/conventional clipping method cause a significant in-band distortion. So this conventional clipping seriously degrades the BER performance, also due to sharp corners of the clipped signal, the adjacent channel leakage ratio (ACLR) reduces. So we have to consider some other clipping method which will give an increased ACLR with a satisfactory PAR reduction [2].

Most practical CFR solutions are based in principle on subtracting a correction signal from the original signal, similar manner in PC-CFR technique, the peaks are detected and then they are processed to form the cancellation signals in order to be subtracted from the original signal [3].

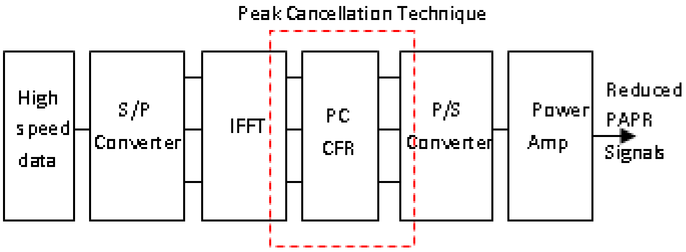

Figure 1: Block Diagram of the Wireless Transmitter

Basically the paper concentrates on the wireless transmitter block where the high speed data is given as an input to the transmitter. Data is converted from serial to parallel points initially after modulation, later IFFT of the data is taken to produce the sub carriers or the OFDM symbols whose crest factor is high. N point IFFT is taken, where N is the number of points. The next step is the application of the peak cancellation crest factor reduction algorithm to reduce the crest factor. Once the crest factor is being reduced after the application of the peak cancellation crest factor reduction algorithm then the parallel data is converted to serial conversion is done. The peak reduced data is amplified by the power amplifier for the purpose of transmission of the symbols in wireless mode. The application of the peak cancellation algorithm reduces the peaks in the signal, hence the power amplifier is not driven to the saturation region instead operates in the linear region with no degradation in efficiency.

PEAK CANCALLATION CFR TECHNIQUE

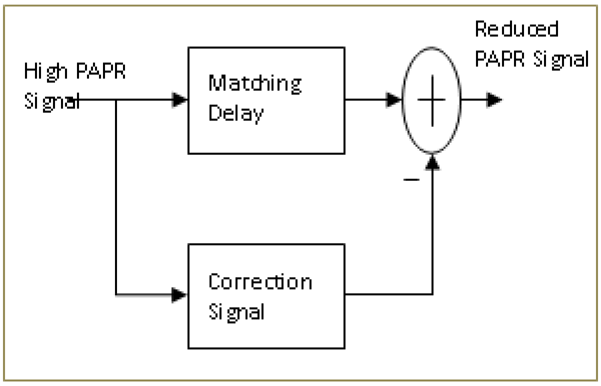

Figure 2: Generalized PC CFR Block Diagram

Most practical CFR solutions are based in principle on subtracting a correction signal from the original signal as shown in Figure 2. The correction signal is a spectrally compliant signal that matches the signal peaks. In Peak Cancellation CFR, the correction signal is a sum of individual cancellation pulses. The pulses are applied by searching for peaks in the signal. Each pulse is the impulse response of a filter that is designed to match the spectral content of the signal.

The peak cancellation method of CFR reduces the peak to average power ratio (PAPR) of a signal by subtracting spectrally shaped pulses from signal peaks that exceed a specified threshold.

The cancellation pulses are designed to have a spectrum that matches that of the CFR input signal and therefore introduce negligible out-of-band interference. In general, the CFR input signal and cancellation pulses are complex, and the peak search is carried out on the signal magnitude. Because the signals are complex, each cancellation pulse must be rotated to match the phase of the corresponding signal peak. The peak magnitude of a given cancellation pulse is set equal to the difference between the corresponding signal peak magnitude and the desired clipping threshold. This method reduces the signal peak magnitudes to the threshold value while preserving the signal phase

PC CFR ALGORATHMIC TEST FLOW

To begin with, a random signal is generated and its PAPR is calculated, then modulation was performed and the serial data is converted to parallel data. The IFFT operation is performed on the parallel data to generate the OFDM signal. The PAPR of the OFDM signal is then calculated, it's found that the PAPR is increased. Now the peak cancellation algorithm is applied to the OFDM signal, the results are plotted and the algorithm is tested.

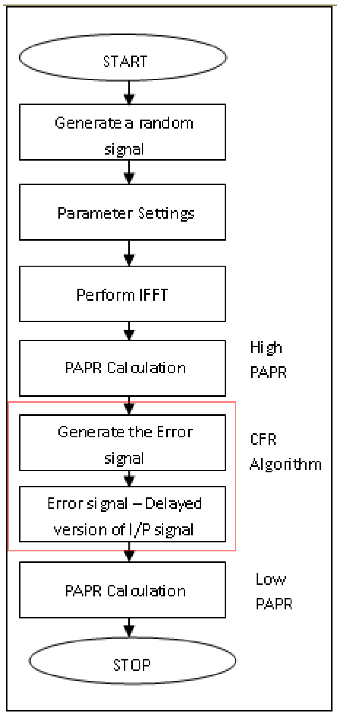

Figure 3: Flow Diagram to Test PC CFR Algorithm

IMPLEMENTED PC CFR ALGORITHM

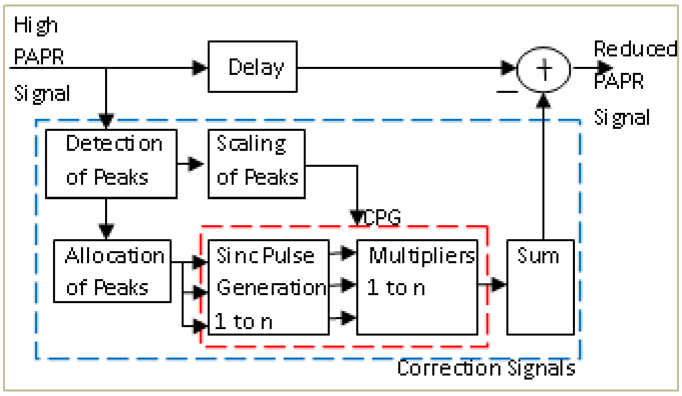

Figure 4: Block Diagram of PC CFR Algorithm

Peaks in the input signal are detected and cancelled to produce a reduced PAPR signal. The peak detector block works on the signal magnitudes to produce a peak location indicator along with magnitude and phase information for each peak. The difference between the peak magnitudes and the clipping threshold is generated by the peak scaling block. The magnitude difference is combined with the phase information to produce the complex weighting that is used to scale the cancellation pulse coefficients. Each CPG can cancel only one peak at a time. The length of the cancellation pulse combined with the number of CPGs determines the rate at which signal peaks can be cancelled.

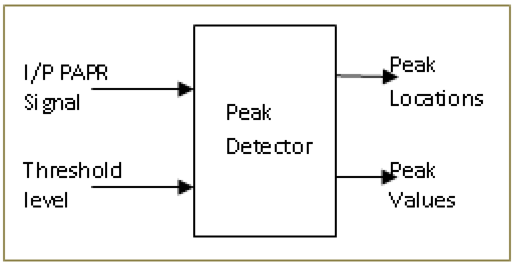

Figure 5: Peak Detector

The allocator block controls the distribution of CPGs to incoming peaks. When a new peak is detected, the allocator assigns an available CPG to the cancellation of that peak. If all CPGs are busy when a new peak is detected, it will not be cancelled. Multiple iterations of the algorithm are necessary to eliminate the peaks that were not cancelled during an earlier pass of the algorithm. The final step in the algorithm is to subtract the summation of the CPG outputs from a delayed version of the input signal.

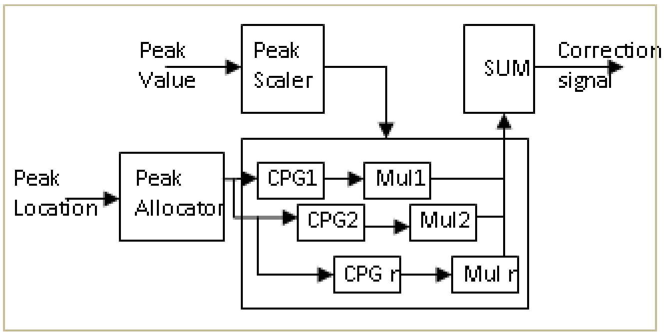

Figure 6: Correction Signal Generator

The allocator controls the assignment of CPG resources to the task of canceling incoming peaks. During startup, all CPGs are available. When the first peak arrives, the allocator assigns the first CPG to cancel it and then tags that CPG as being allocated. Once allocated, a CPG becomes unavailable for the length of the cancellation pulse (in samples). When subsequent peaks arrive, the allocator steps through the status of each CPG and assigns the first one available. Peaks that arrive when all CPGs are currently busy will not get cancelled and must be picked up by a subsequent iteration of the algorithm.

There are times when the input signal exhibits a high density of over-threshold peaks in clusters (for example, two non-adjacent carriers). This can lead to less than optimal allocation of CPGs and contribute to high peak re-growth. To mitigate the degradation, an allocator spacing parameter is used to prevent cancellation of peaks that are closer than some specified distance from an already allocated peak.

Each cancellation pulse generator or CPG produces an unscaled copy of the stored cancellation pulse. The cancellation pulse is designed to occupy the same frequency bands as the input signal. The cancellation pulse coefficients can be obtained using any preferred filter design methodology and are computed off-line before being written to the PC-CFR design. Memory that is external to the design may be used to store multiple sets of cancellation pulse coefficients corresponding to pre-determined carrier configurations. Transferring a selected set of coefficients into the PC-CFR memory can be handled with some simple multiplexing circuitry.

Once the cancellation pulses are generated from the CPGs, the un-scaled version of the cancellation pulses are scaled using a scaling factor, later all the output of the CPGs are summed using a summer to produce the cancellation pulse which is to be subtracted from the OFDM signal.

ALGORITHM SIMULATION

MATLAB is used for simulation purpose. A random signal is first generated quadrature amplitude modulation is performed to transmit the random signal. OFDM signal is generated by performing IFFT on the modulated random signal. Figure 7 shows the random signal, scatter plot and the generated OFDM signal respectively.

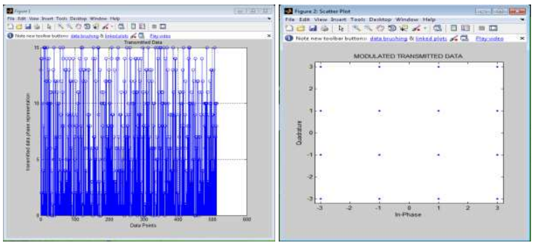

Figure 7: Random Signals and Scatter Plot of Modulated Random Signal

The OFDM signals are generated by taking the IFFT of the random signals, once the IFFT has been taken then the PAPR of the generated OFDM signal increases. Initially the random signal had a PAPR of around 4dB where as the PAPR of the OFDM signal seemed to be around 12dB.

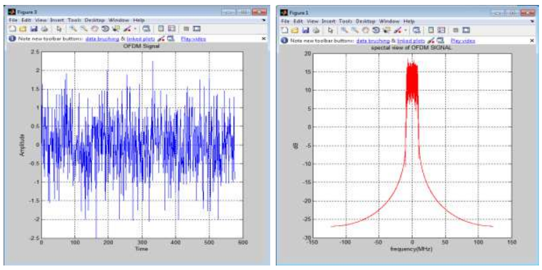

Figure 8: Generated OFDM Signal (Time and Frequency Domain View)

The OFDM signal is clipped and the reduction of the PAPR is observed, initially the PAPR of the OFDM signal was around 12dB, due to clipping the results of PAPR has been reduced to around 1dB.

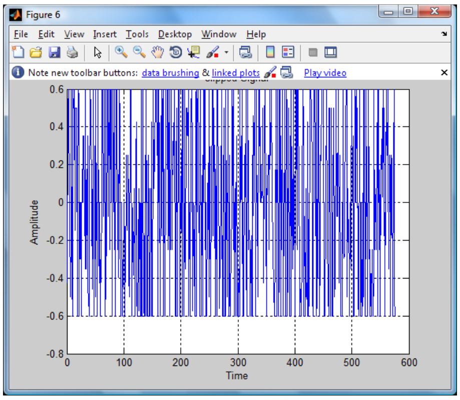

Figure 9: Clipped OFDM signal

Table 1: PAPR Values of the Signals in figure 7, 8 & 9

No	Signals	PAPA value
1.	Random signal (I/P signal)	4.7001 dB
2.	OFDM signal (After IFFT)	11.0956 dB
3.	Clipped OFDM Signal (After detecting the peaks and clipping the peaks)	0.0352 dB

Cumulative Distribution Frequency plots (CCDF) are plotted to check the PAPR of the signal. Here the CCDF plot of the OFDM signal is compared with the clipped signal. The tabulation clearly shows that there is a reduction in the PAPR after clipping the signal hence clipping the signal formed one of the bases for the peak cancellation crest factor reduction algorithm.

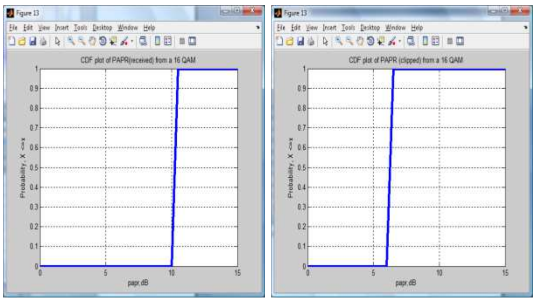

Figure 10: CCDF Plots of the OFDM Signal and the Clipped Signal

Table 2: Comparison of CCDF Plots of OFDM Signal and Clipped Signal

Max Amplitude Clipped AT	PAPR Before Clipping	PAPR After Clipping
O.1	10	6
0.2	10	6
0.3	10	6
0.4	10	6
0.5	10	7
0.6	10.1	7.2
0.7	10.2	7.4
0.8	10.5	7.5

A threshold is set and all the peaks above the threshold are detected and plotted, the peaks are reduced by comparison of the local peaks detected. The time domain and the frequency domain results are plotted below (Peak reduction without sinc pulse).

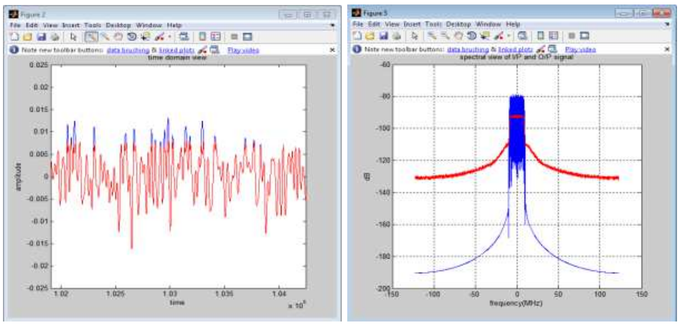

Figure 11: Time and Frequency Domain View of the Peak Reduced Signal

Sinc pulse is generated by the cancellation pulse generator. A single cancellation pulse generator generates a single sinc pulse. Sinc pulses are chosen because spectrum of sinc pulse is rectangular in nature and they can be matched with the spectrum of the OFDM signal easily. Figure 12 shows the sinc pulse generated using MATLAB.

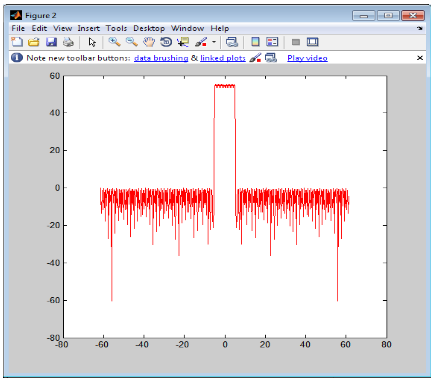

Figure 12: Generated sinc pulse

The peak cancellation crest factor reduction technique is applied on the generated OFDM signal, each sinc pulse generated is allocated to the detected peaks and the cancellation pulse is generated which is then subtracted from the final signal to obtain the reduced PAPR signal. The PAPR reduction is also achieved. The error vector plot is also shown below; the blocks are also viewed in simulink.

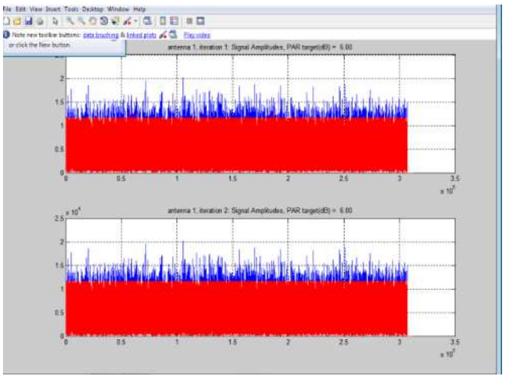

Figure 13: Time Domain View of the PAPR Reduced OFDM Signal

Figure 14: Output Signal Along with CCDF Plot

The FPGA (ML 605) kit is interfaced with the spectrum analyze ie. CRO to view the results and verify the spectrum. Initially a threshold of 5dB was set and it was found that a reduction of PAPR from 9dB to 5dB was possible. The algorithm was also tested for a threshold of 7dB and a reduction of 5dB of crest factor was achieved.

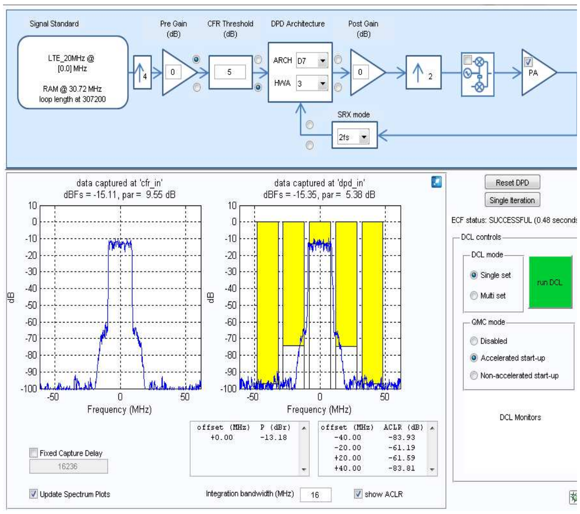

Figure 15: Spectrum Monitoring of PC-CFR (Threshold – 5)

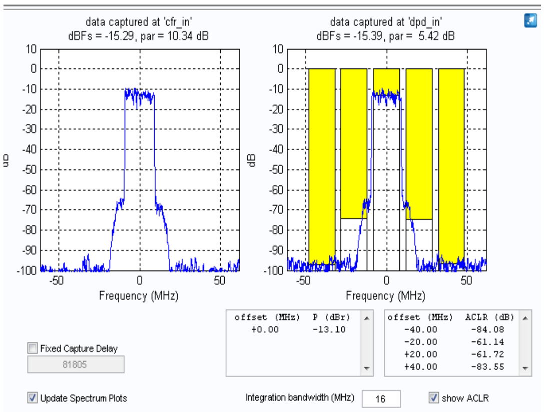

Figure 16: Spectrum Monitoring of PC-CFR

Table.3: Implemented PAPR Values with their Respective Threshold Values

Set Threshold Value	Reduction in PAPR
5 dB	9dB to 5 dB
7 dB	Around 5 dB

CONCLUSIONS

The main objective of this paper is to generate an algorithm used to reduce the crest factor. The algorithm has to be tested and should be shown that the crest factor reduction algorithm can be implemented practically. Hence the problem of the power amplifier to move to the saturation region during the encountering of high peak signals can be overcome. The defective issue of OFDM technology is the PAPR problem, so it is very important to improve the high PAPR issue of OFDM signal. Most of the reducing technology for high PAPR needs the complexity calculation, but it relies on the high performance DSP technology. In this paper, we have generated the PC-CFR algorithm and simulated this algorithm to show that it is a practical technique that can be readily implemented. More than 5dB of PAPR reduction can be achieved with this algorithm.

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